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RESEARCH AND DEVELOPMENT
REPORT i-121
MAY 1967

Interim Report

VISIBILITY OF TASK LIGHTS

Subproject SF 013 12 08, Task 4601

HERBERT LARRIMORE

UNITED STATES NAVY MINE DEFENSE LABORATORY
P A N A M A   C I T Y ,   F L O R I D A

ABSTRACT

A task light array was set up in the vicinity of the calibrated light range at the U. S. Navy Mine Defense Laboratory to determine the minimum lamp wattage that would satisfy the legal requirement of visibility of 2 miles when the atmospheric transmission is 70 percent per mile. The requirement is satisfied when power is reduced from 90 to 36 watts in each red light and from 45 to 12 watts in the white light. The output of each red light is thus reduced from about 35 candelas to about 10 and the output of the white light from 80 candelas to 10. The reduced outputs are expected to alleviate fleet complaints of impairment of night vision during replenishment operations at sea.

ADMINISTRATIVE INFORMATION

Subproject SF 013 12 08, Task 4601, was established by Bureau of Ships letter F013-12-08, serial 660W-2521, of 7 June 1963 for development, improvement, and testing of navigational lights and special signaling lights. Naval Ship Engineering Center (formerly Bureau of Ships) letter 9640/5, serial 660W-1141, of 8 April 1966 requested the Laboratory to conduct tests to determine the minimum wattage lamps required in a task light array to provide the legal 2-mile visibility of the array.

The tests described in this report were conducted during the period 15 April 1966 to 2 September 1966.

APPROVED AND RELEASED 20 MARCH 1967

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Subj: MDL Unclassified Report 1-121 of May 1967; comments concerning

1. The U. S. Navy Mine Defense Laboratory conducted a series of tests to determine the minimum lamp wattage required in task lights to meet the 2-mile visibility requirement.

2. This report describes the tests and results of the study and is forwarded for information and retention.

J. D. W. BOROP

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TABLE OF CONTENTS

	Page No.
INTRODUCTION	3
FIELD TESTS	3
Test Setup	3
Test Procedure	9
Test Results	9
CONCLUSIONS	9
APPENDIX A - LABORATORY TESTS	13
APPENDIX B - NOTES ON FIELD TESTS	17
REFERENCES	24

LIST OF ILLUSTRATIONS

Figure No.		Page No.
1	Task Light Array on Stage I	4
2	Task Light Array (Standard Layout)	5
3	Task Light Control Unit	6
4	Control Unit Functional Diagram	7
5	External and Internal View of Light with Red Lens	8
A1	Chromaticity Diagram for Lower Red Light	15
B1	Horizontal Luminous Intensity Distribution Curves for Task Lights with 15-Watt Lamps	18

LIST OF ILLUSTRATIONS (CONT'D)

Figure No.		Page No.
B2	Vertical Luminous Intensity Distribution Curves for Task Lights with 15-Watt Lamps	19
B3	Horizontal Luminous Intensity Distribution Curves for Task Lights with 7-Watt Lamps	20
B4	Vertical Luminous Intensity Distribution Curves for Task Lights with 7-Watt Lamps	21
B5	Spectral Energy Distribution Curves for Task Lights with 15-Watt Lamps	22
B6	Spectral Energy Distribution Curves for Task Lights with 7-Watt Lamps	23

INTRODUCTION

Fleet Commands have reported disturbing impairment of night vision caused by the task lights during replenishing operations at sea. International regulations require that such lights be visible for 2 miles when atmospheric transmission is 70 percent per mile. A reduction of lamp wattage was proposed to minimize impairment of vision while satisfying the visibility requirement.

The visibility of the standard task light array has been determined in sea tests at the U. S. Navy Mine Defense Laboratory (MDL) with various combinations of lamps and wattage. The array satisfied the minimum visibility requirement when the total power in each of the two red lights was reduced from 90 to 35 watts and that in the white light from 45 to 12 watts. Since any reduction of local light intensity would enhance night vision, such reduction of power should be acceptable without question except for possible directional variations.

The spectral energy distribution of the lamps used in the task lights was also determined with the view of recommending more favorable lamps. This study is discussed in Appendix A.

FIELD TESTS

TEST SETUP

The test setup was designed for measurements that would indicate minimum usable wattages for lights in the task light array. The array was mounted on Stage I, the MDL offshore platform, as shown in Figures 1 and 2. The control unit shown in Figures 3 and 4 was used to dim each light and for measurements of current and voltage. The number of lamps in each light could also be changed to vary the brightness (Figure 5). A calibrated light range (Reference 1) on Stage I was used to monitor continually the rate of light transmission through the atmosphere.

The observers who participated in the field tests were military personnel who serve as lookouts on board the USS VENTURE (MSO-496). Each observer was given an industrial type eye examination with the

(Text continued on page 9)

FIGURE 1. TASK LIGHT ARRAY ON STAGE I

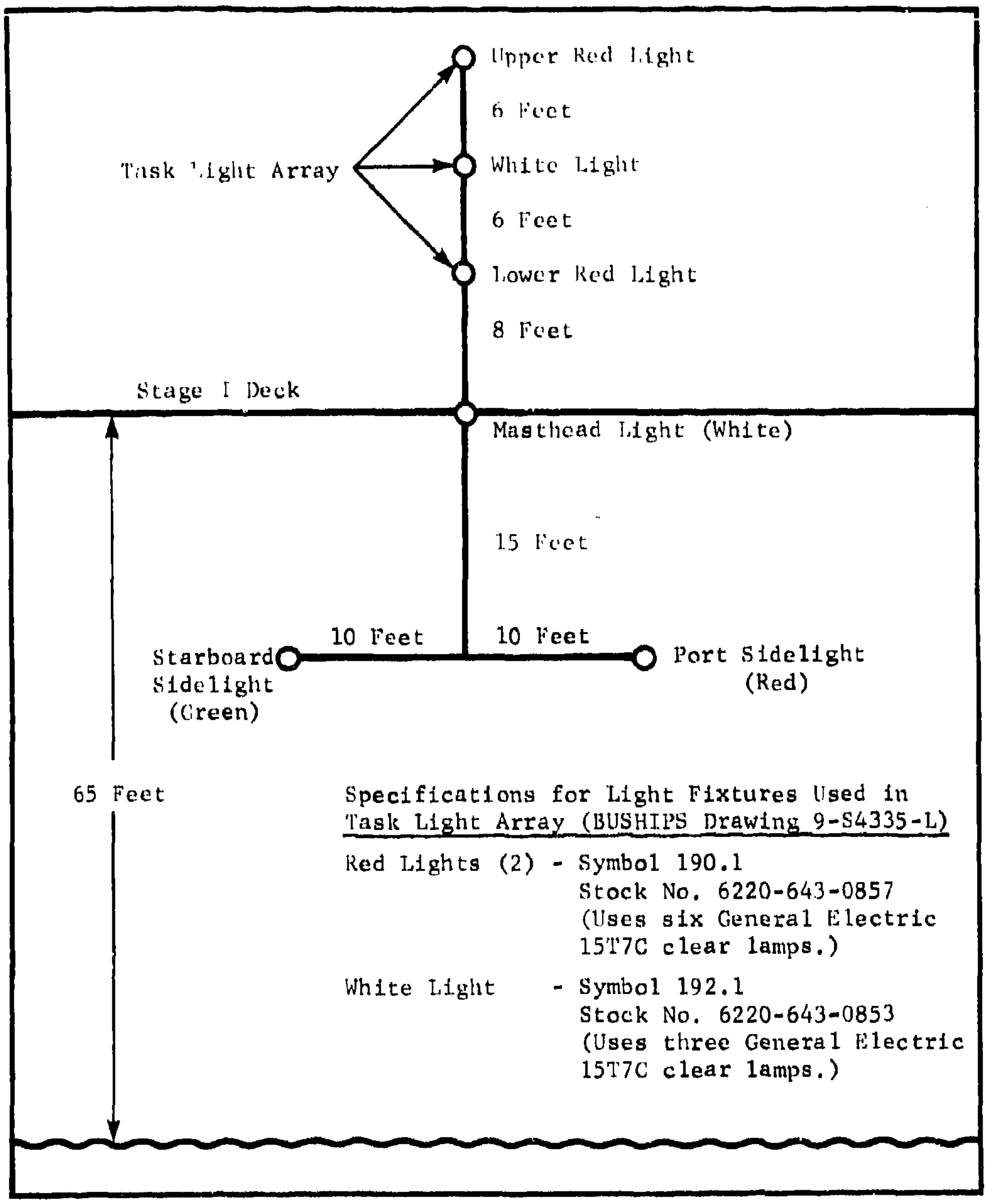

FIGURE 2. TASK LIGHT ARRAY (STANDARD LAYOUT)

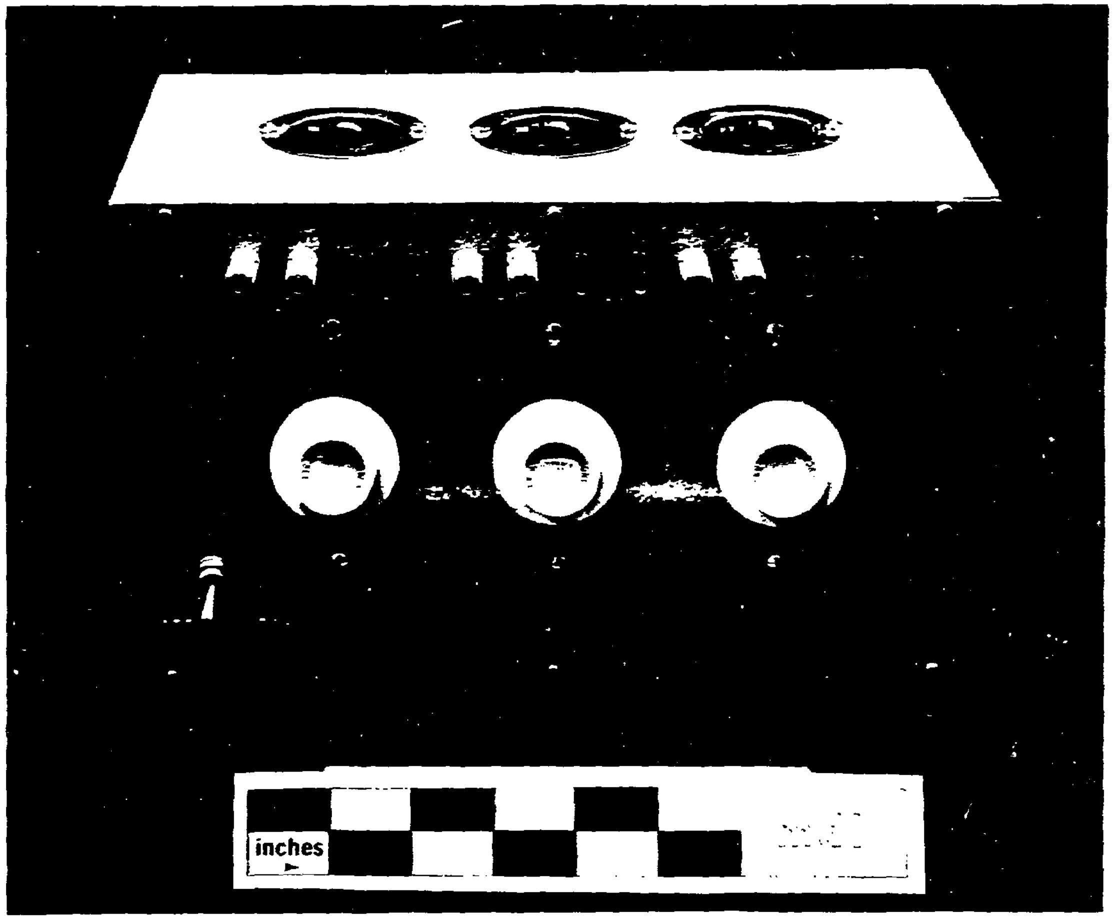

FIGURE 3. TASK LIGHT CONTROL UNIT

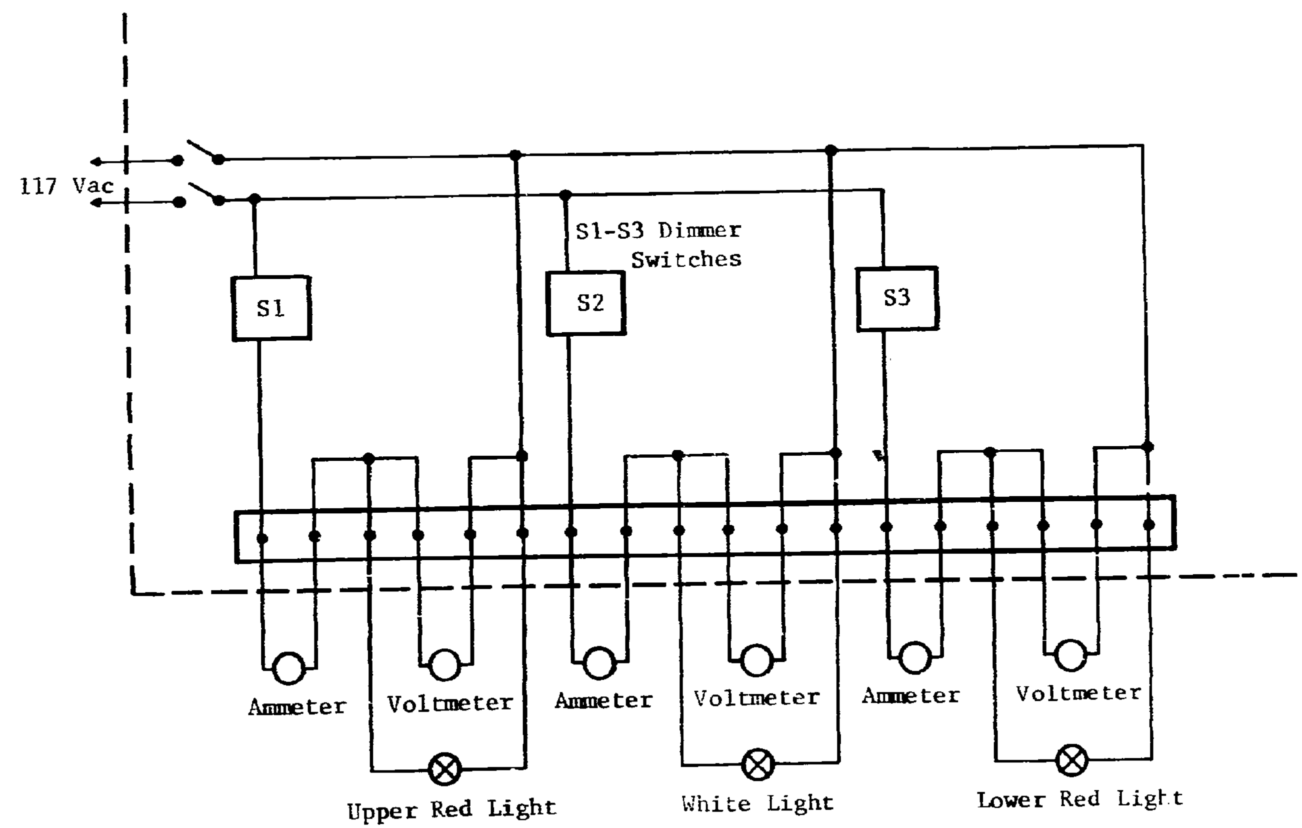

FIGURE 4. CONTROL UNIT FUNCTIONAL DIAGRAM

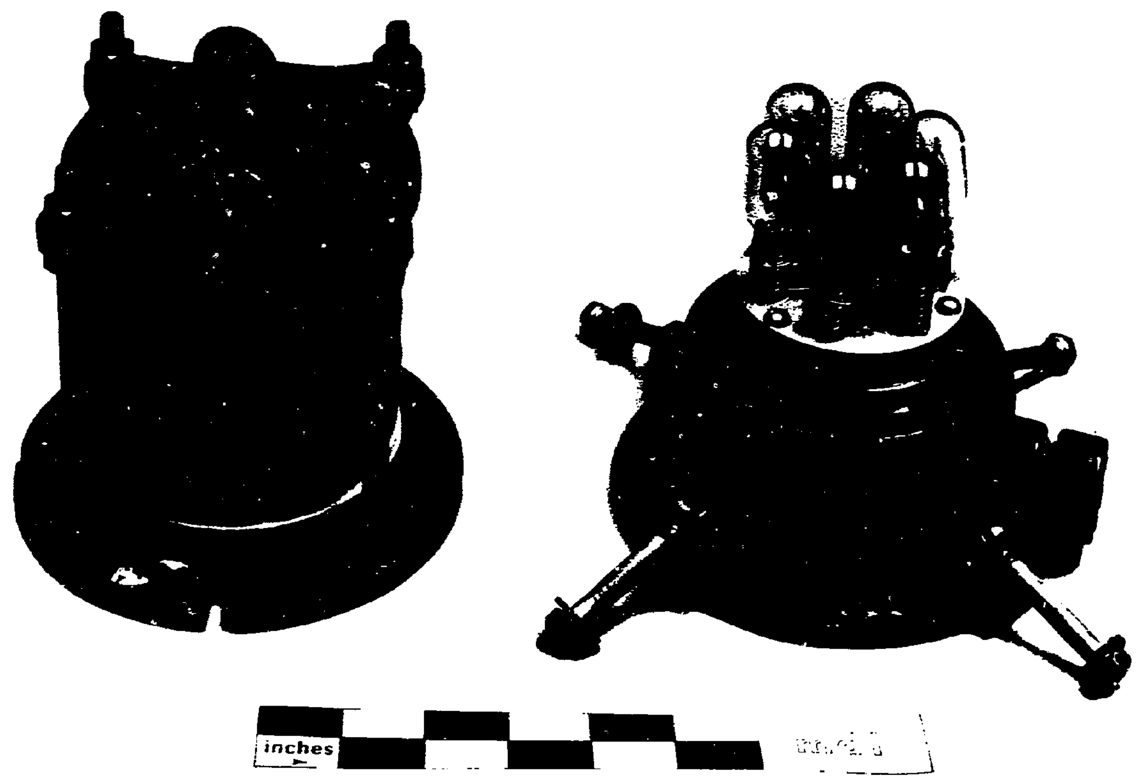

FIGURE 5. EXTERNAL AND INTERNAL VIEW OF LIGHT WITH RED LENS

Bausch & Lomb Ortho-Rater. Only observers with 20-20 vision and normal color perception were selected to participate in visibility tests. At least three observers were on duty during all measurements and generally stood 4-hour watches. All observations of task light visibility were made with the unaided eye.

TEST PROCEDURE

The observers were stationed on the bridge as the USS VENTURE moved away from and returned toward Stage I. With allowance for navigational error and possible sway in the lamp mast, the estimated test path width was 10 degrees. The ship's radar operator provided range marks every quarter of a mile, and the observers recorded all lights they could see at each mark. Stage I was blacked out except for the lights under test, and all lights on the ship that would have been visible to the observers were secured. The intensity of the task lights was varied by adjusting the dimmers or by changing lamps between runs.

TEST RESULTS

Table I summarizes the results of the task light visibility tests. The data are presented in the order of collection. The first observations were made with 15T7C lamps at full intensity and the last with 7C7 lamps at a total of 35.6 watts in the red lights and 12 watts in the white light. For the last 11 observations, the destroyer array side-lights (Reference 2) were turned on to see if they interfered with visibility. The threshold range figures given are averaged for the number of observations indicated, most of them being well above the 2-mile criterion.

A discussion of other than standard lamps used in the field tests is provided in Appendix B.

CONCLUSIONS

The legal 2-mile visibility requirement is satisfied in the direction of the test path by the standard task light array when the power of each red light is reduced from 90 to 35 watts, and that of the white light from 45 to 12 watts. These ratings are based on a test path 10 degrees wide to allow for error in navigation and light alignment.

TABLE 1

VISIBILITY TEST DATA

Light	Number of Lamps	Watts	Threshold Range (Miles)	Number of Observations*	Atmospheric Transmission Percent/Mile
Upper Red	6	90	2.9	6	**
Lower Red	6	90	2.2	6	**
White	3	45	5.5***	1	**
Upper Red	6	90	2.3	5	**
Lower Red	6	90	1.9	5	**
White	3	40	7.4	4	**
Upper Red	6	90	2.5	6	**
Lower Red	6	90	2.1	6	**
White	3	16.9	6.0***	3	**
Upper Red	6	66	2.8	5	**
Lower Red	6	66	2.5	5	**
White	3	40	4.6***	2	**
Upper Red	5	78	2.4	7	62.8
Lower Red	5	78	2.0	7	62.8
White	2	32	3.5***	7	62.8
Upper Red	5	68	2.0	4	60.8
Lower Red	5	68	1.8	4	60.8
White	2	32	4.8***	3	60.8
Upper Red	5	67.2	2.6	5	60.8
Lower Red	5	67.2	1.8	5	60.8
White	2	28.5	3.5***	5	60.8
Upper Red	5	68.6	2.3	8	62.6
Lower Red	5	68.6	2.1	8	62.6
White	2	24.1	6.9	3	62.6

*An observation is defined as a single determination by one observer of the range at which the light is barely visible.

**The atmospheric transmission for these observations is not available because the recorder pen was off the chart.

***The run was terminated at this point with the light still visible.

TABLE 1 (CONT'D)

VISIBILITY TEST DATA

Light	Number of Lamps	Watts	Threshold Range (Miles)	Number of Observations*	Atmospheric Transmission Percent/Mile
Upper Red	5	60.0	2.2	7	68.4
Lower Red	5	60.0	2.1	7	68.4
White	2	19.7	3.5***	7	68.4
Upper Red	5	50.7	2.5	6	68.4
Lower Red	5	50.7	2.2	6	68.4
White	2	16.3	3.5***	6	68.4
Upper Red	6	43.3	2.2	3	70
Lower Red	6	43.3	2.0	3	70
White	3	21.0	3.5***	3	70
Upper Red	6	43.3	2.1	3	70
Lower Red	6	43.3	2.0	3	70
White	3	18.5	3.5***	3	70
Upper Red	6	43.3	2.8	2	60.8
Lower Red	6	43.3	2.1	2	60.8
White	2	14.2	3.5***	2	60.8
Upper Red	6	28.7	2.3	4	60.8
Lower Red	6	28.7	1.9	4	60.8
White	2	14.0	3.5***	4	60.8
Upper Red	5	35.6	2.4	2	55
Lower Red	5	35.6	2.1	2	55
White	2	14.0	3.5***	2	55
Upper Red	5	35.6	2.3	14	55
Lower Red	5	35.6	2.2	14	55
White	2	12.0	3.5***	14	55
		Destroyer Array Sidelights On			
Upper Red	5	35.6	2.5	11	55
Lower Red	5	35.6	2.6	11	55
White	2	12.0	3.5***	11	55

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APPENDIX A

LABORATORY TESTS

INSTRUMENTATION

Measurements of luminous intensity were made with a Macbeth illuminometer manufactured by Leeds and Northrup. For these visual measurements, two neutral density filters and two red vinylite filters, previously calibrated in the Macbeth, were used to extend the range and to match the desired color. Each task light was mounted on an alidade at one end of a Leeds and Northrup optical bench. An opal glass plaque of known reflectance was mounted at the opposite end of the optical bench. Illumination was measured with the Macbeth illuminometer while the lights were rotated in the horizontal and vertical planes. The luminous intensity of each light was calculated for each orientation.

The spectral energy distributions of the task lights were determined with a modified Beckman Model DB spectrophotometer. The internal standard light sources were removed, one channel was blocked, and an entrance port was cut in the rear apron of the cabinet for illumination of the entrance slit by an external source. The external standard source and the task light to be examined were placed with suitable mirrors for illumination at the entrance slit.

To obviate correction for nonlinear response of the spectrophotometer, the standard color temperature source and the light to be tested were compared at each wavelength setting without changing the instrumentation. These measurements were repeated at intervals of 5 millimicrons throughout the visible spectrum from 400 to 700 millimicrons. In this region the most convenient known source is illuminant A, a tungsten filament lamp operated at a color temperature of 2854°K. The data include the reading for the unknown light being tested and for illuminant A, designated R_s and R_a, respectively. The spectral energy distribution E_λ of illuminant A is known (Reference 3), and the spectral energy distribution E_s of the unknown light can be calculated from the equation:

$$E_s = \frac{R_s E_\lambda}{R_a}$$

E_s is then plotted against wavelength in a spectral energy distribution curve.

CHROMATICITY

A particular color is specified in terms of relative proportions of red, green, and blue, referred to as the trichromatic coefficients. If the proportions of the trichromatic coefficients are designated x, y, and z percent, respectively, then for a given light beam $x + y + z = 100$. The composition of any color can be plotted in terms of two of the values, the third being that required to bring the total to 100.

Chromaticity is determined by either the weighted ordinate method or the selected ordinate method. The weighted ordinate method outlined in Reference 4 was used in these determinations.

In this method, the value of E_s for each wavelength, as determined previously, is multiplied by the tristimulus values of the spectrum color as given in Reference 3. The products obtained, $\bar{x}$, $\bar{y}$, and $\bar{z}$ tristimulus values, are then determined for each wavelength in increments of 5 millimicrons throughout the visible spectrum. The columns of figures for $\bar{x}$, $\bar{y}$, and $\bar{z}$ are then summed to give values for X, Y, and Z. That is,

$$\Sigma\bar{x} = X, \quad \Sigma\bar{y} = Y, \text{ and } \Sigma\bar{z} = Z$$

The trichromatic coefficients are computed as

$$x = \frac{X}{X + Y + Z}$$

$$y = \frac{Y}{X + Y + Z}$$

$$x + y + z = 1$$

These trichromatic coefficients were plotted on chromaticity charts shown in Figure A1.

LUMINOUS INTENSITY

The relationship between the luminous intensity of a source and the illumination produced at a distance is

$$\text{Illumination} = \frac{\text{luminous intensity in candelas*}}{\text{square of distance from source}}$$

*The candela is a unit of luminous intensity, identical with the "new candle" defined in 1948 but favored in international usage. One candela equals 0.981 international candle but is based on a more exactly reproducible source.

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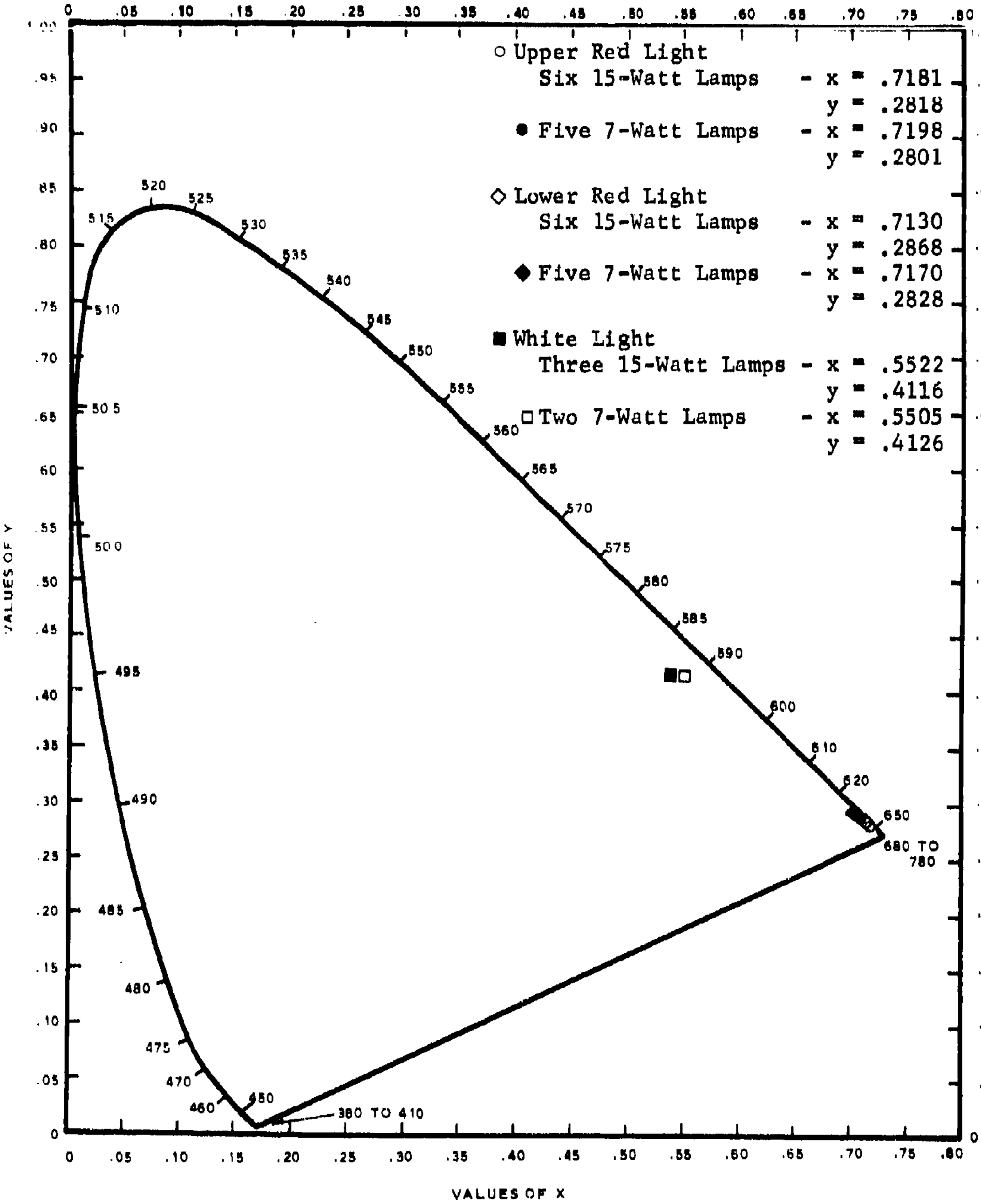

FIGURE A1. CHROMATICITY DIAGRAM

Through the use of this fundamental relationship based on definition and the inverse square law, the candle power of the task lights in various directions was determined. The lights were mounted on the optical bench 5 feet from the opal glass plaque. All light to the plaque was cut off except that emitted by the task light. The illumination at the plaque was measured with the Macbeth illuminometer. The Macbeth reading, in foot candles multiplied by the square of the distance between the light and plaque, gives the candle power in that direction. Vertical distribution curves of the light source were obtained by rotating the light about a horizontal axis through its center. Similarly, horizontal distribution curves were obtained by rotating the light about the vertical axis through its center. Care was taken to direct the light normal to the plaque, and to view the plaque at an angle as near normal (always less than 25 degrees) to its surface as practical.

APPENDIX B

NOTES ON FIELD TESTS

TEST RESULTS

Horizontal and vertical luminous intensity distribution curves for 15-watt lamps are shown in Figures B1 and B2, respectively, and for 7-watt lamps in Figures B3 and B4, respectively. Spectral energy distribution curves for task lights using 15-watt and 7-watt lamps are shown in Figures B5 and B6, respectively. The location of the task lights in the International Commission on Illumination (CIE) chromaticity diagram is shown in Figure A1.

NOTES

The 7C7 lamps used in the field tests, although not standard, were used because they gave the desired light output and were readily available. The light center length of the 7C7 lamp is approximately one-eighth inch shorter than that of the 15T7C. This difference may explain the elevation of the vertical luminous intensity curves shown in Figure B4. The 7C7 lamp is not considered suitable for shipboard use where it would be subject to vibration.

The fresnel lenses used in the task lights appeared nonuniform in both thickness and curvature. In addition, the red lenses were not of uniform density. These imperfections, as well as the asymmetric spacing when two or five lamps were used, and the masking effects of the four long bolts that secure the top of the light, appeared to contribute to the lack of uniformity in the horizontal luminous intensity that is apparent in Figure B1.

It appears that a more suitable lamp arrangement would utilize one dual filament lamp at the center of the drum lens, provided the circuit problems and safety factors are resolved.

When the white light was operated at 12 watts with two 7C7 lamps operating through a dimmer, the color temperature shifted toward the red as indicated in Figure A1. Should these lamps be replaced with others rated at 12 watts and operating at full power, visibility would be enhanced as a result of chromaticity shift from the red toward the more visible portion of the spectrum.

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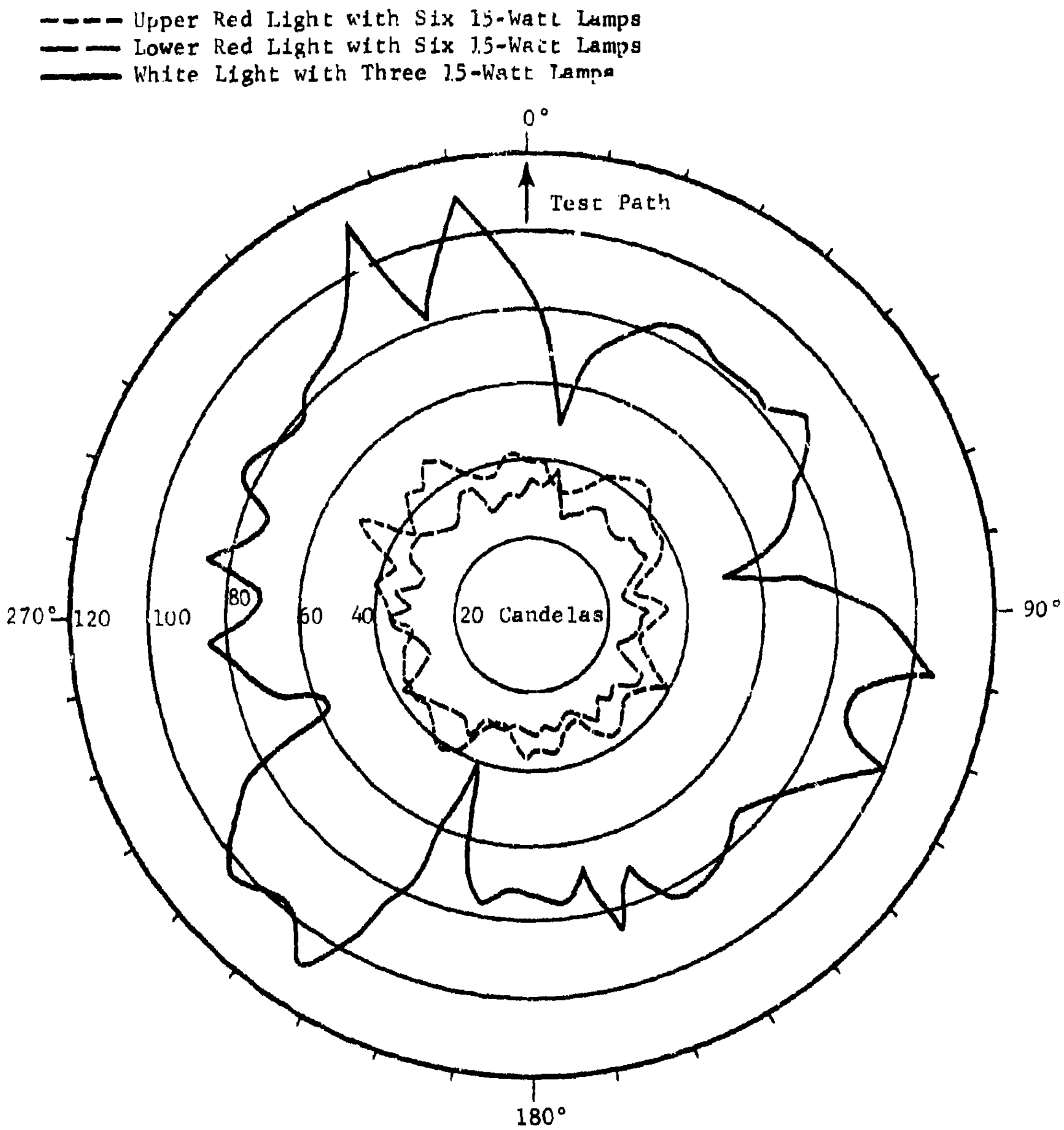

FIGURE B1. HORIZONTAL LUMINOUS INTENSITY DISTRIBUTION CURVES FOR TASK LIGHTS WITH 15-WATT LAMPS

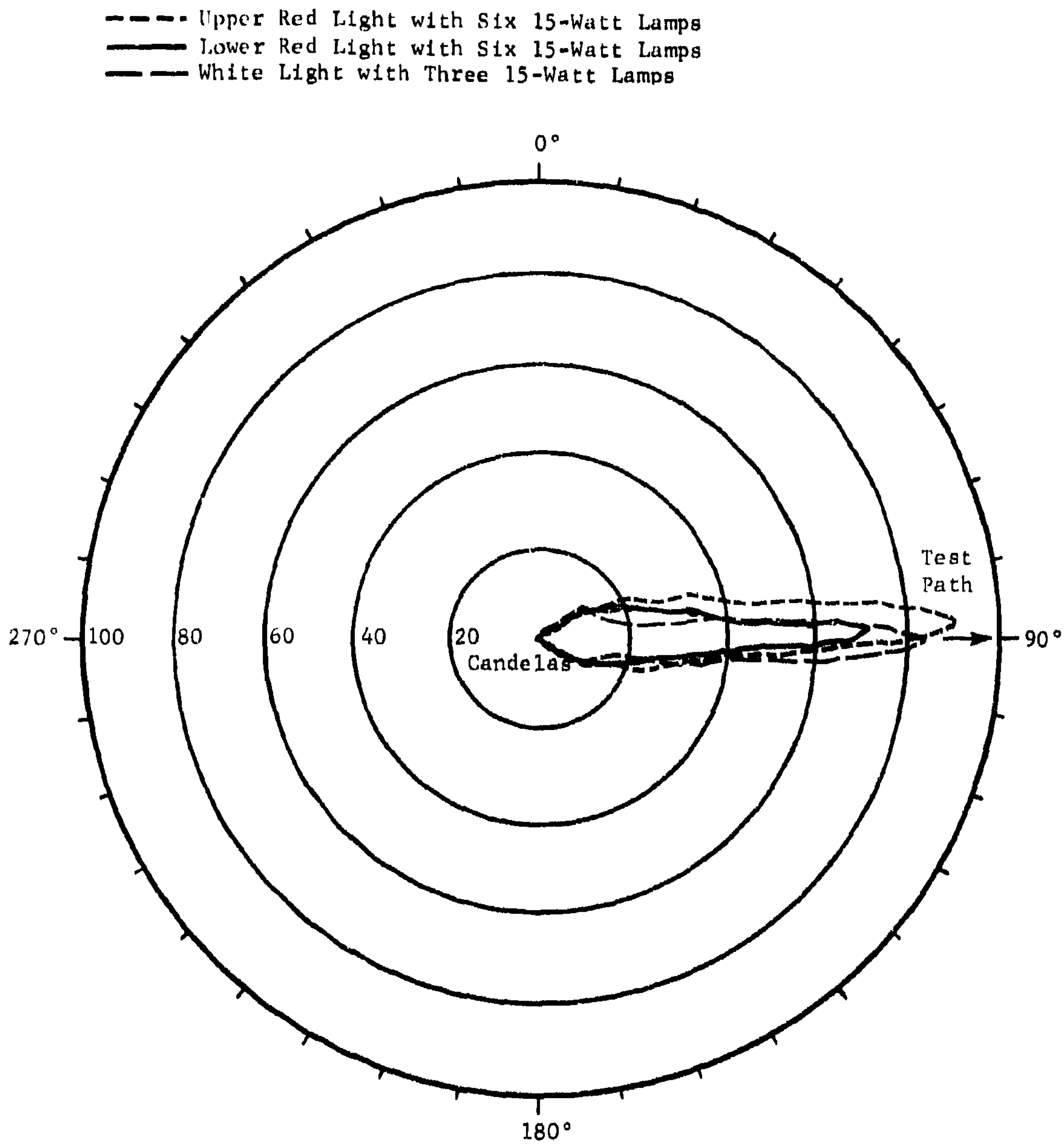

FIGURE B2. VERTICAL LUMINOUS INTENSITY DISTRIBUTION CURVES FOR TASK LIGHTS WITH 15-WATT LAMPS

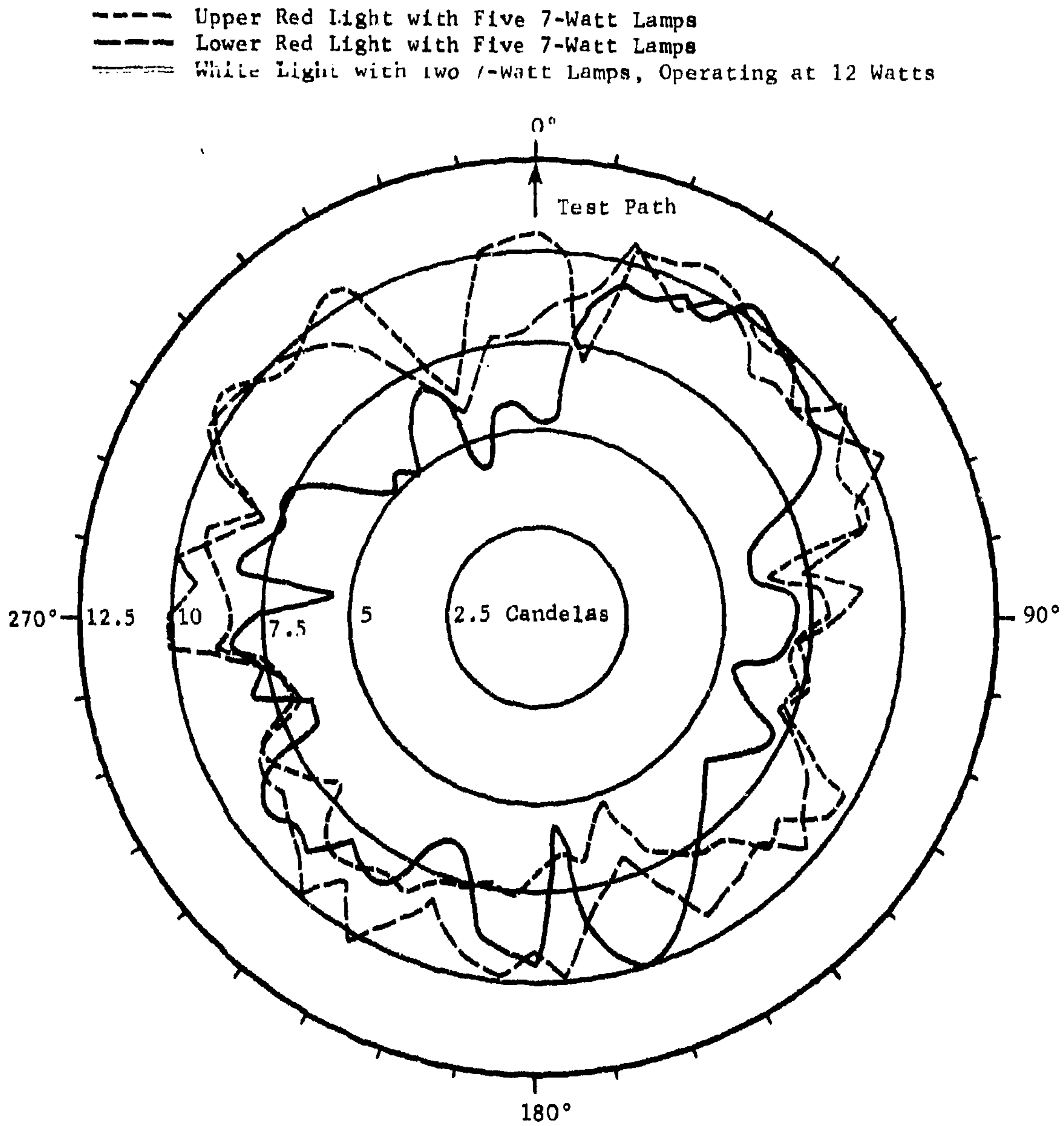

FIGURE B3. HORIZONTAL LUMINOUS INTENSITY DISTRIBUTION CURVES FOR TASK LIGHTS WITH 7-WATT LAMPS

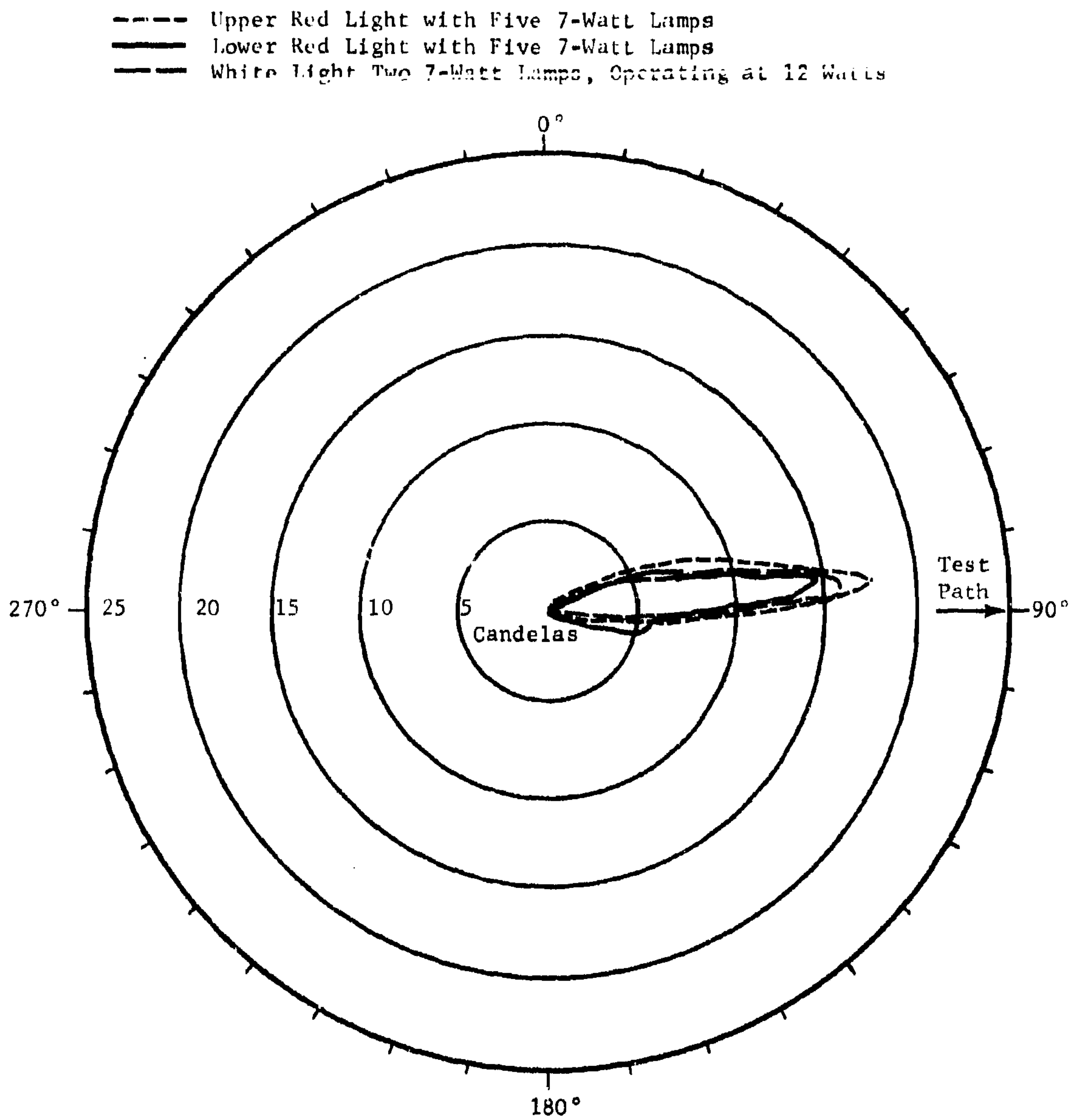

FIGURE B4. VERTICAL LUMINOUS INTENSITY DISTRIBUTION CURVES FOR TASK LIGHTS WITH 7-WATT LAMPS

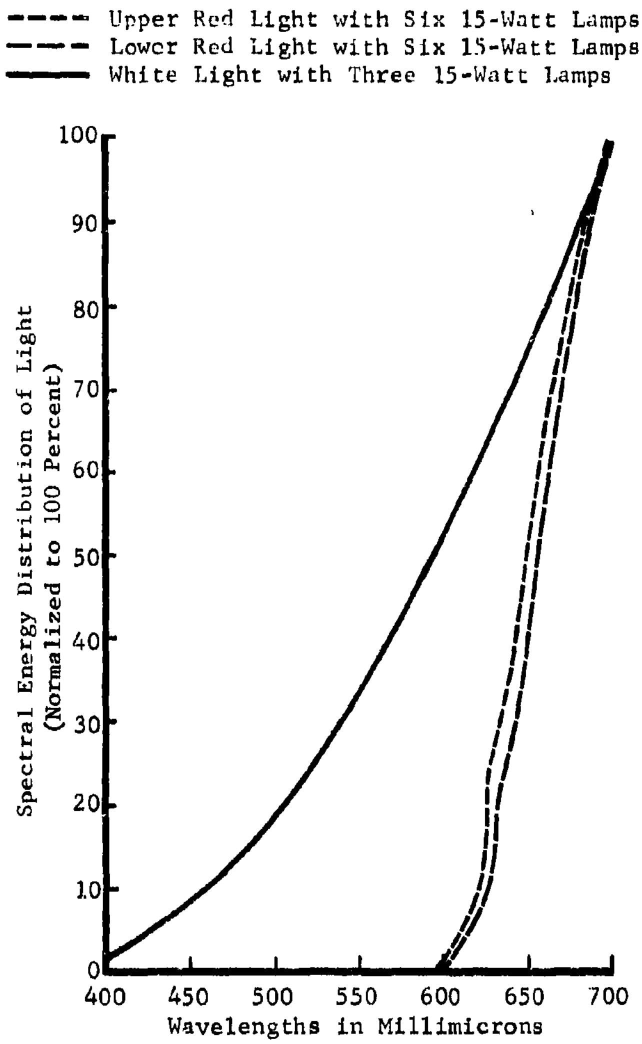

FIGURE B5. SPECTRAL ENERGY DISTRIBUTION CURVES
FOR TASK LIGHTS WITH 15-WATT LAMPS

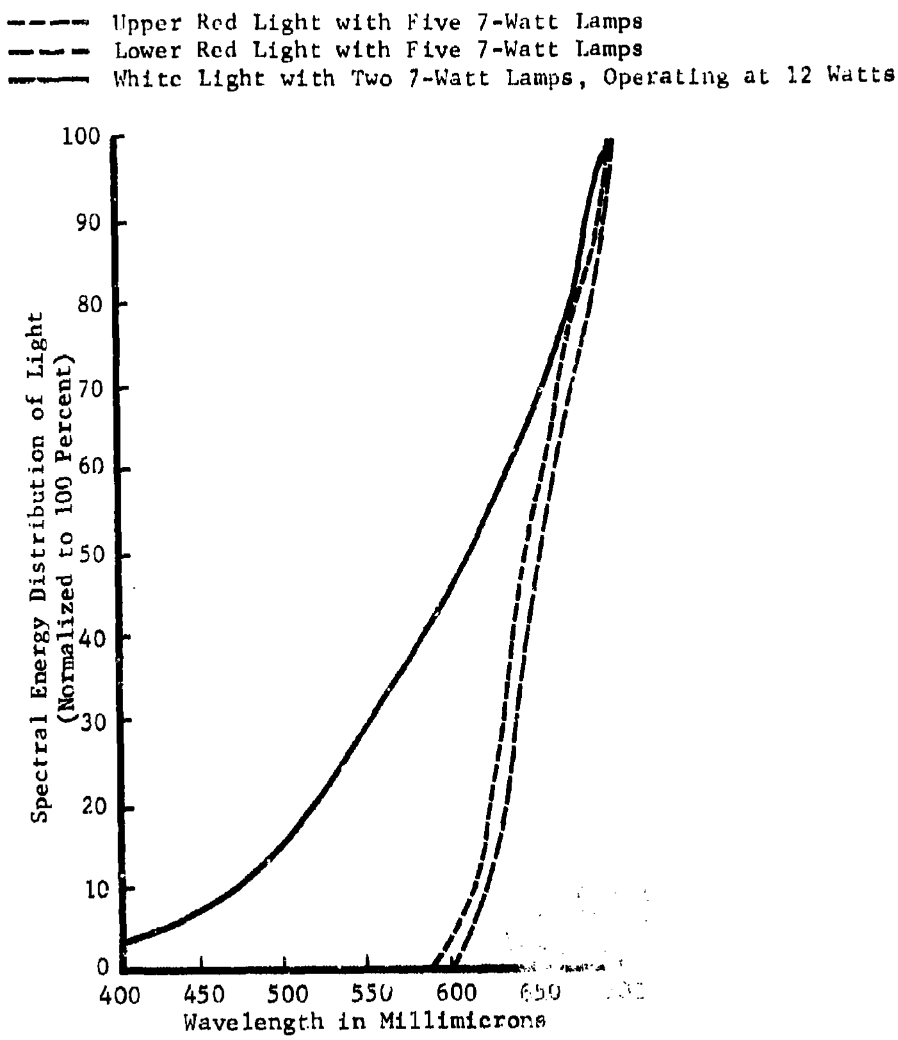

FIGURE B6. SPECTRAL ENERGY DISTRIBUTION CURVES FOR TASK LIGHTS WITH 7-WATT LAMPS

RECOMMENDATION

It is recommended that task lights use lamps with a color temperature approximately that of illuminant A and so arranged that each red light radiates between 8 and 11 candelas and the white light radiates between 11 and 12 candelas.

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13. ABSTRACT

A task light array was set up in the vicinity of the calibrated light range at the U. S. Navy Mine Defense Laboratory to determine the minimum lamp wattage that would satisfy the legal requirement of visibility of 2 miles when the atmospheric transmission is 70 percent per mile. The requirement is satisfied when power is reduced from 90 to 36 watts in each red light and from 45 to 12 watts in the white light. The output of each red light is thus reduced from about 35 candelas to about 10 and the output of the white light from 80 candelas to 10. The reduced outputs are expected to alleviate fleet complaints of impairment of night vision during replenishment operations at sea.

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NO. 3

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2. Navigational lights.
I. Title
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III. Subproject SF 013 12 08
IV. Task 4601

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1. Task lights - Visibility-measurement.
2. Navigational lights.
I. Title
II. Larrimore, Herbert
III. Subproject SF 013 12 08
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NO. 1

1. Task lights - Visibility-measurement.
2. Navigational lights.
I. Title
II. Larrimore, Herbert
III. Subproject SF 013 12 08
IV. Task 4601

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NO. 2

1. Task lights - Visibility-measurement.
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CARD 1	CARD 2	CARD 3	CARD 4

U. S. Navy Mine Defense Laboratory. Report i-121.
VISIBILITY OF TASK LIGHTS by Herbert Larrimore.
May 1967. 24 p., photos., illus UNCLASSIFIED

References: 4 refs.
A task light array was set up in the vicinity of the calibrated light range at the U. S. Navy Mine Defense Laboratory to determine the minimum lamp wattage that would satisfy the legal requirement of visibility of 2 miles when the atmospheric transmission is 70 percent per mile. The requirement is satisfied when power is reduced from 90 to 36 watts in each red light and from 45 to 12 watts in the white light. The output of each red light is thus reduced from about 35 candelas to about 10 and the output of the white light from 80 candelas to 10. The reduced outputs are expected to alleviate fleet complaints of impairment of night vision during replenishment operations at sea.

NO. 3

1. Task lights - Visibility-measurement.
2. Navigational lights.
I. Title
II. Larrimore, Herbert
III. Subproject SF 013 12 08
IV. Task 4601

UNCLASSIFIED

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NO. 4

1. Task lights - Visibility-measurement.
2. Navigational lights.
I. Title
II. Larrimore Herbert
III. Subproject SF 013 12 08
IV. Task 4601

UNCLASSIFIED

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NO. 1

1. Task lights - Visibility-measurement.
2. Navigational lights.
I. Title
II. Larrimore, Herbert
III. Subproject SF 013 12 08
IV. Task 4601

UNCLASSIFIED

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NO. 2

1. Task lights - Visibility-measurement.
2. Navigational lights.
I. Title
II. Larrimore Herbert
III. Subproject SF 013 12 08
IV. Task 4601

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